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# DEVELOPMENT OF AN EMERGENCY UNDERWATER ESCAPE BREATHING SYSTEM FOR CH124 SEAKING AIRCREW

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## ABSTRACT

This Technical Report details the research and development of an underwater escape breathing system for use by Canadian Forces aircrew faced with the risk of water immersion and underwater escape from a downed aircraft. The report details preliminary investigation into: the U.S. Coast Guard Rebreather System, The Robertshaw Underwater Escape Breathing System, and the Submersible Systems Inc.(SSI) Emergency Breathing System (EBS); and the procurement, modifications, and testing of the SSI EBS for use by CH124 Sea King aircrew, and subsequent recommendation for its adoption by the Canadian Forces.

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## INTRODUCTION

Sudden immersion into cold water is known to induce an immediate life-threatening physiological response that may result in drowning or at least reduce the chances of successful egress following aircraft ditching. Goode (1) and Cooper (2) have shown that sudden immersion into cold water creates an intense gasp reflex that appears to be neurogenic in origin, possibly through reflex stimulation of ventilation from the direct effects of cold on the skin thermal sensors. Following the gasp reflex, there is a hyperventilatory drive that can lead to hypocapnia that may progress to loss of consciousness and drowning. The gasp reflex alone can result in an individual aspirating cold water with sudden vagal arrest of heart action and death by drowning. Should an individual be fortunate enough to survive the gasp reflex, their breath-holding ability while submerged in cold water is significantly compromised to the point where underwater escape may not be possible. Eberwein (4) reports that Haywood at the University of Victoria, British Columbia, determined that fit individuals who could hold their breath for 108 seconds in 70 degree F air could hold their breath for only 12 seconds on sudden immersion into 50 degree F water. Fear and physical exertion could be expected to decrease breath holding ability even further.

These immediate physiological reactions to sudden cold water immersion are of paramount importance to Canadian Forces (CF) aircrew who fly the CH124 Sea King helicopter. This aircraft typically operates at altitudes below 100 feet above sea level over cold water from both fixed base and destroyer (DDH) facilities. Historically, these aircrew are most at risk from sea water immersion (3). Its low profile operation carries high probability of sudden water impact from mechanical or human failure. Since 1962, 11 of these aircraft have ditched into water. One such accident occurred at Morris Lake near Canadian Forces Base Shearwater in July 1983. Through human error, this aircraft pitched nose down during a practice single engine take-off. The violent pitch down resulted in the main rotor severing the tail pylon and the aircraft came to rest inverted in 20 feet of water. All four crew escaped successfully; two were swept rearwards by in-rushing water, and one of these escaped only by luck. The consequences might have been tragic had the water been deeper. Recommendation 5.g. of the Board of Inquiry requested that the Defence and Civil Institute of Environmental Medicine with National Defence Headquarters (NDHQ), give higher priority to the development of an emergency breathing supply for Canadian Forces (CF) aircrew who work routinely at low level over water.

This report outlines the historical development of such an emergency underwater escape breathing system for CH124 aircrew.

## BACKGROUND

Early in 1979, the United States Coast Guard (USCG) experienced an H-3 helicopter accident off Cape Cod in which four of the five aircrew drowned while attempting underwater escape. This accident was the latest in a series of similar tragedies and prompted the USCG to develop an underwater escape breathing system. The prototype system that emerged that year consisted of a modified dual-cell life preserver. One cell of the preserver included an oral inflation tube and 28 gram carbon dioxide cartridge; the other cell consisted of a mouthpiece with breathing tube and a

12 litre compressed breathing-oxygen cartridge (Fig. 1). On immersion, the oxygen cartridge is manually started by a pull toggle that inflates the left cell of the preserver with 100% oxygen. The 8.64 kilogram buoyant force created was determined to pose " ... no significant decrease to mobility during escape" (5). The USCG combined the rebreather into a prototype life preserver/survival vest combination in 1981.

The re-breather system was physiologically evaluated by the United States Navy's Experimental Diving Unit (Panama City, Florida) early in 1981 (6). The primary criticism of the system arising from the study was the significant suppression of the hypoxic drive and a tendency toward the development of hypercapnia and loss of consciousness while re-breathing 100% oxygen underwater (the oxygen is converted to carbon dioxide). Removing the hypoxic drive caused the subjects to continue re-breathing well beyond the point where their mental state would be adequate for helicopter egress. It was therefore recommended that the 100% oxygen be replaced with a 60:40 nitrogen/oxygen mixture to create enough dyspnea to warn of impending carbon dioxide intoxication and unconsciousness. Despite this recommendation, the USCG decided to proceed with re-breather development using 100% oxygen because of the significantly longer breathing times afforded by 100% oxygen over either air or 40% oxygen.

In February 1980 the Directorate of Flight Safety (DFS) at NDHQ requested that the Directorate of Aerospace Support Engineering (DAS Eng) monitor the development of the USCG underwater escape rebreather (UER) system so that the CF might adopt a similar system for aircrew who routinely face ditching risks (7). The following September, DCIEM's Medical Life Support Division (MLSD) was tasked by the DAS Eng to monitor USCG developments or develop a CF-unique emergency escape rebreather device (8). This tasking was accepted by DCIEM in November 1980 (9), and assigned project number 14H12-10 (now 3752A-PR5CB-12A/3/2).

## DEVELOPMENT AND TESTING

In April 1981, DCIEM inquired into the possibility of obtaining a USCG re-breather system for evaluation through an Air Standardization Coordinating Committee Test Project Agreement (10); however, it was not possible to proceed further with this request since only two prototypes were in existence and there was an unresolved conflict over the use of 100% oxygen as the breathing medium. At this point, MLSD undertook a feasibility study of modifying the current CF life-preservers to incorporate a similar rebreather capability and concluded that " ... the number of alterations ... required to incorporate this feature are numerous (and) would require a complete re-engineering with design changes" (12).

As the future of the USCG system was in question, DCIEM decided to proceed with the investigation of alternative compressed gas systems. A commercially available breathing system designed for emergency underwater escape based on the SCUBA design had been identified (13). This system, manufactured by the Robertshaw Controls Company (Anaheim, California) and available through Dyer and Miller Bros. Ltd. (Weston, Ontario), consisted of a coiled stainless steel tube reservoir containing 130 litres of air compressed to 5000 psig. From the reservoir, a 56 cm hose with in-line quick disconnect fitting connected to a miniature demand regulator mouthpiece (Figure 2). The air supply was started by pulling a ring at the base

of the unit. Two of these units were procured for evaluation in March 1981. Underwater evaluations at DCIEM by the Canadian Experimental Diving Division (CEDD) during the Fall of 1981 revealed that during a 75 watt workload on an underwater bicycle ergometer at 10 and 30 fsw, the average breathing times were 3 and 2.5 minutes respectively. However, it was found that the regulator mouthpiece occasionally filled with water, requiring excessive purging to clear, thus depleting the air supply more quickly. The leakage was thought to arise from inadequately designed flapper valves on the regulator mouthpiece exhaust port or from some design deficiency in the regulator itself. Consultation with the manufacturer revealed that re-design would result in the price per unit becoming prohibitive. As a result, no serious follow-on action was undertaken (14).

In the latter half of 1982, MLSD identified a commercially available emergency breathing system (EBS) designed for divers that could have potential as an underwater escape system for aviators. This EBS, manufactured by Submersible Systems Inc. (SSI) (Huntington Beach, California) consists of a 53 cm long, 5 cm diameter, 56.6 cu.dm. (2 cu.ft.) aluminum cylinder containing 56 litres of air pressurized to 1800 psig. A single-stage demand regulator incorporating a twist-turn on/off knob, rubber mouthpiece, purge button, pin-type pressure gauge, and a refill port is attached directly to the cylinder head. The cylinder itself is U.S. Department of Transport (DOT) 3E rated and can be continuously used without ever being re-hydro tested. Overpressurization during refill is prevented by the incorporation of a brass disc designed to burst at 2700 psig (Figure 3). The cylinder itself is designed with a minimum burst pressure of 6000 psig. The EBS is available in single or dual cylinder combinations (Figures 4A and 4B).

Operation of the EBS is simple. The rubber mouthpiece is placed in the mouth either before or after the knob is rotated counterclockwise to open the bottle. The user either exhales or depresses the PURGE button momentarily to clear the regulator of water. Breathing may then proceed normally through the demand regulator.

Several of these units were purchased by DCIEM/MLSD in April 1983 and evaluated by DCIEM (CEDD) during 16 test dives at 10 and 30 FSW. Breathing duration times during a moderate swimming workload averaged one minute 36 seconds and one minute 18 seconds respectively for a single EBS cylinder. It was recommended that some of these units be procured by NDHQ for user trials and flight evaluations (14). NDHQ responded by requesting that MLSD identify possible storage/mounting positions for the EBS in the Sea King Helicopter (15).

To provide a unit that would integrate with the survival backpack, SSI was requested to modify several units to a Mark II design by inserting a 60 cm long high-pressure hose between the bottle head and the mouthpiece regulator (Figure 5A and B). A visit to Canadian Forces Base Shearwater by the MLSD Project Officer early in 1984 resulted in several recommendations for the EBS (16):

a. the EBS be mounted on the seat pan for the TACCO and AESO positions;

b. the EBS Mark II be evaluated for possible incorporation in the backpack;

c. additional EBS units be mounted in the rear of the cabin for use by passengers and crew in that area; and

d. all individuals receive pool training in the proper use of the EBS.

By May 1984, MLSD had acquired 12 standard (MK I) bottles and four Mark II bottles from SSI for flight test purposes. During the Aviation Life Support Equipment Project Review Meeting held at DCIEM 26-27 June 1984, it was decided that all aircrew participating in the EBS trial would require appropriate training on underwater breathing techniques and hazards. Canadian Forces Base Shearwater Base Aviation Life Support Equipment Officer (BALSEO), in consultation with DCIEM and the Command Surgeon (Air Command), was recommended as the training programme coordinator. In July, Air Command Headquarters formally approved the EBS trial (17), and the training programme was drafted a few weeks later (18).

In January 1985, the MLSD project officer visited Canadian Forces Base Shearwater's BALSEO to deliver 10 Mark I and eight Mark II EBS bottles for trial, and in February the Directorate of Air Requirements (DAR) issued the User Trial Directive DAR 1/85 Letter of Assignment (19). The trial was authorized to be conducted during the period 1 March to 30 June 1985. Following receipt of the Trial Directive, Air Command Headquarters assigned the conduct of the trial to Maritime Air Group Headquarters (MAGHQ) as DEVAL A3035 (20) with the coordinating authority vested in the Senior Staff Officer Evaluations and Requirements (SSO E&R). MAGHQ in turn issued the project directive for the developmental evaluation of the CH124 emergency breathing system in May 1986 (21), HT 406 Squadron to conduct the evaluation and submit the final report. final report.

At the same time that the CF was evaluating the EBS system, the USN was conducting an evaluation of both the original EBS and the USCG rebreather systems. Formal operational evaluations commenced in March 1985. Testing of the USCG rebreather by the USN Air Test Center at Patuxent River showed that the volume of the rebreather cell decreased with water depth (hydrostatic pressure), and there was some difficulty in the oxygen cell inflating sufficiently to open the protective outer casing. Hydrostatic pressure also appeared to affect the volume distribution of oxygen within the bladder in relation to the breathing tube. Below 15 fsw, pressure tended to compress the lower half of the breathing cell when the subject was in the upright position, and compress the top half of the breathing cell if the subject was inverted. Due to the centralized attachment point of the breathing tube (Figure 1), this tended to either restrict flow to the mouthpiece or overpressurize the mouthpiece respectively. Further problems with hose crimping (hose pinch) and crotch strap and bladder displacement (riding-up) were identified (25). Although the USCG system was able to provide a required two minute breathing supply at 20 fsw and 55 degrees F, the buoyancy of the inflated oxygen cell was found to interfere with test subjects' ability to locate and manoeuvre out of emergency escape hatches. As a result, Naval Air Systems Command terminated testing of the rebreather system (22). The original EBS was then successfully tested and approved for production. Hardware deliveries to the US Fleet began in September 1986 (23).

In July 1986, MAGHQ SSO E&R signalled a deficiency report on the EBS to DCIEM/MLSD (24). The report suggested that although the majority of the

trial participants preferred the Mark II configuration, several modifications were required prior to trial completion. These included:

a. shortening of the high pressure hose by 13 cm to 47 cm;

b. providing a swivel-type mouthpiece; and

c. incorporating a more reliable pressure indicating system.

The report also suggested that the bottle be incorporated into the survival backpack for all crew members.

Orders for six EBS bottles incorporating these recommendations (Mark III) (Figure 6) were placed with SSI in September 1986, and they were received at MLSD in January 1987. Five of these bottles were forwarded to SSO E&R for evaluation in February. Discussion with the SSO E&R on 28 May 1987 revealed that the evaluation had been completed and the final report was being drafted. At the Aircrew Life Support Equipment Project Review Meeting held at DCIEM on 9, 10 June 1987, SSO E&R stated that the EBS had been accepted and the official DEVAL Report would follow in due course. During the Aircrew Life Support Equipment Project Review Meeting held at DCIEM 12-13 January 1988, MAGHQ SSO E&R 2-2 stated that the EBS Mark III had been recommended for fleet installation, and must be incorporated into the re-designed slim line survival backpack. This was confirmed by message a few days later (26).

## CONCLUSIONS

The emergency underwater escape breathing system Mark III has been successfully tested in both the laboratory and operational setting to fulfil the requirements for an emergency underwater escape breathing air source for CH124A Sea King aircrew following aircraft water ditching.

## RECOMMENDATIONS

It is recommended that the Mark III Emergency Breathing System manufactured by Submersible Systems Inc. (Huntington Beach, California) be procured and incorporated into the survival backpack for all CH124A crew members.

Suitable training must be conducted on the use of the EBS, incorporating underwater escape technique and physiology.

This EBS may also have potential life-saving uses in other CF aircraft.

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17. Message: AIRCOM WINNIPEG REQR 090 051930Z Jul 84.

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Figure 1. United States Coast Guard prototype rebreather system. Horsecollar type lifepreserver open to show dual-cell concept.

Figure 2. Robertshaw underwater escape device.

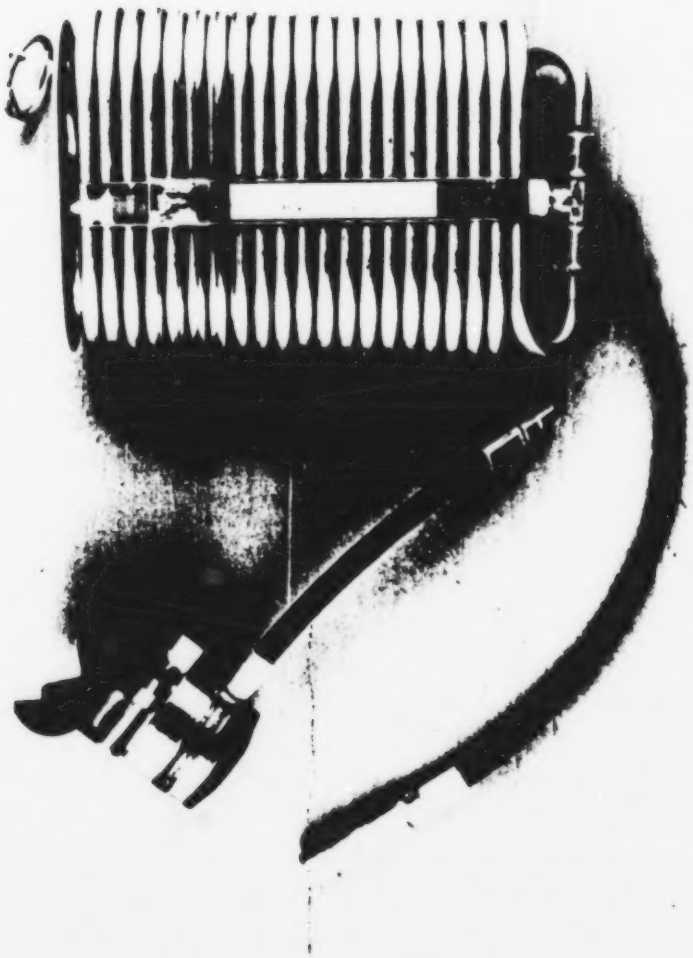

Figure 3. Submersible Systems EBS Regulator Cross Section
CH124 Sea King

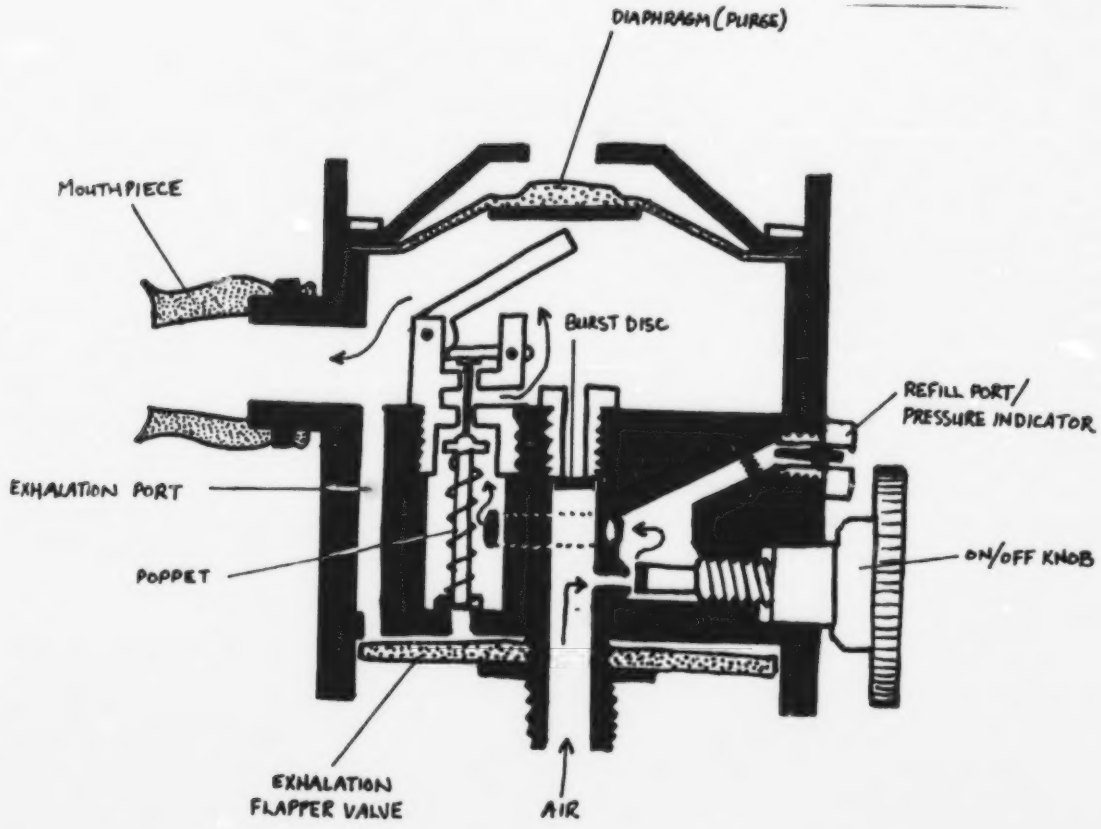

Figure 4A. Submersible Systems Inc. Emergency Breathing System (EBS)
Dual cylinder model

Figure 4B. Submersible Systems Inc. Emergency Breathing System (EBS) Single cylinder model

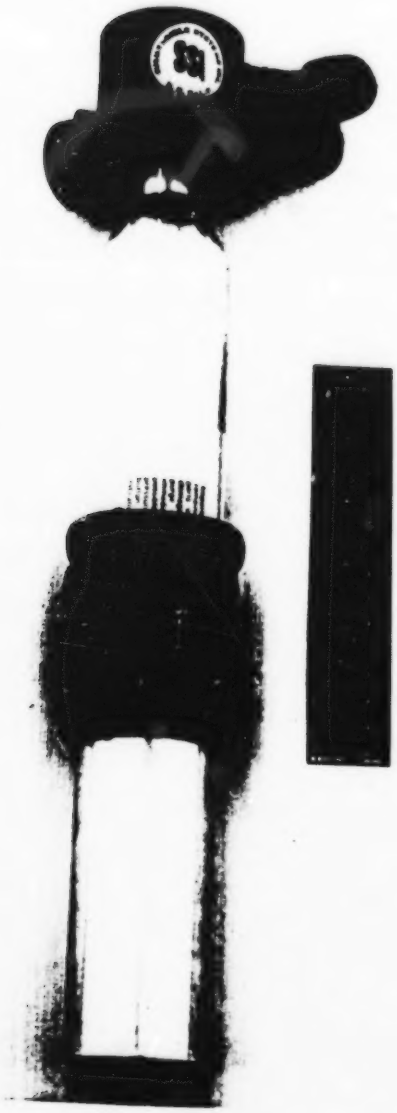

Figure 5A . Modified EBS (Mark II) showing position in survival backpack and 24 inch high pressure line from bottle to regulator mouthpiece

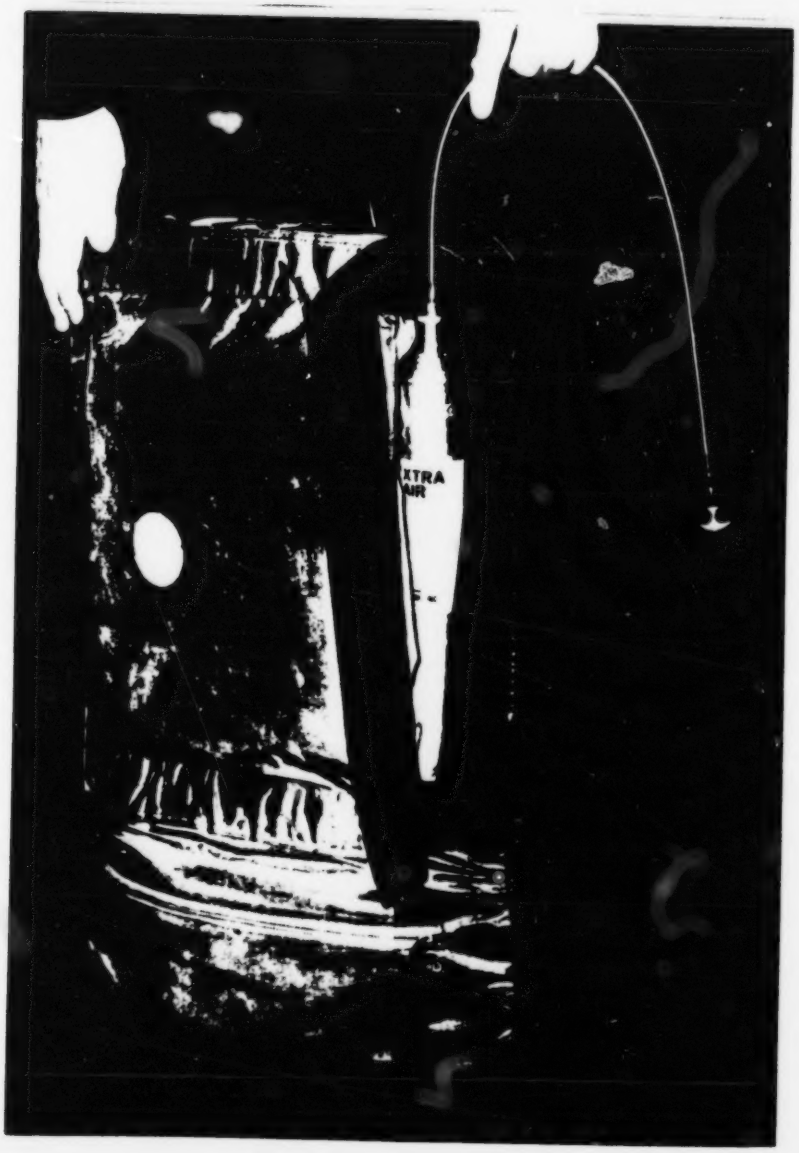

Figure 5B. Modified EBS (Mark II) showing regulator mouthpiece positioning

Figure 6. Modified EBS (Mark III) as accepted by MAGHQ as a result of DEVAL/A3035